HW 3.3 | Ch. 13 # 30, 31, 54, 59

13.30)

a) mole fraction = ?

$$y = \frac{p}{p_{tot}} \qquad p_{tot} = p_{CO_2} + p_{O_2} + p_{N_2} = 100 + 10$$

$$y_{CO_2} = \frac{p_{CO_2}}{p_{tot}} = \frac{20}{100} = .20 \qquad y_{O_2} = \frac{p_{O_2}}{p_{tot}} = \frac{40}{100} = .20 \qquad y_{N_2} = \frac{50}{100} = .50$$

mass fraction = ?

$$mf = \frac{m}{m_m} =$$

$$m_{CO_2} = N_{CO_2} M_{CO_2} = (20\ kmol)(44\ kg/kmol) = 880\ kg$$

$$m_{O_2} = N_{O_2} M_{O_2} = (5\ kmol)(32\ kg/kmol) = 160\ kg$$

$$m_{N_2} = N_{N_2} M_{N_2} = (50\ kmol)(28\ kg/kmol) = 1400\ kg$$

$$m_m = m_{N_2} + m_{O_2} + m_{CO_2} = 3240\ kg$$

$$mf_{CO_2} = \frac{m_{CO_2}}{m_m} = \frac{880\ kg}{3240\ kg} = .2716$$

$$mf_{O_2} = \frac{m_{O_2}}{m_m} = \frac{160\ kg}{3240\ kg} = .2163$$

$$mf_{N_2} = \frac{m_{N_2}}{m_m} = \frac{1400\ kg}{3240\ kg} = .4321$$

b) molecular weight = ?

$$M_m = \frac{m_m}{N_m} = \frac{3240\ kg}{100\ kmole} = 32.40\ kg/kmole$$

C_v = Table A.2.

$$C_v = mf_{CO_2} C_{v\,CO_2} + mf_{O_2} C_{v\,O_2} + mf_{N_2} C_{v\,N_2}$$

$$= (.2716)(.657)(.2163)(.658) + (.4321)(.743)$$

$$C_v = .6945\ kJ/kg\cdot K$$

$$R = \frac{R_u}{M_m} = \frac{8.314\ kJ/kmol\,K}{32.40\ kg/kmol} = .2566\ kJ/kg\cdot mol$$

c) $C_p = ?$

$C_p = C_v + R$

$= .6945 + .2566$

$C_p = .951 \text{ kJ/kg·K}$

$k = ?$

$k = \frac{C_p}{C_v} = \frac{.9511}{.6945} = 1.370$

13.39) mass flow rate ($\dot{m}$) $= ? = \frac{\dot{V}}{v}$

$Y_{air} = 1 - Y_{CH_4}$

$= 1 - .15$

$Y_{air} = .85$

$M_m = Y_{CH_4} M_{CH_4} + Y_{air} M_{air}$ ← Tables A-1

$= (.15)(16 \text{ kg/kmol}) + (.85)(28.97 \text{ kg/kmol})$

$M_m = 27.02 \text{ kg/kmol}$

$\dot{V} = \frac{n V_d}{2} = \frac{(3000 \text{ rpm})(.005 m^3)}{2} = 7.5 m^3/min$

$v = \frac{R_u T}{M_m P} = \frac{(8.314 \text{ kPa·m}^3/\text{kmol})(293 K)}{(27.02 \text{ kg/kmol})(600 kPa)} = 1.27 m^3/kg$

$\dot{m} = \frac{\dot{V}}{v}$

$= \frac{7.5}{1.127}$

$\dot{m} = 6.66 \text{ kg/min}$

12.54)

a) $T_f = ?$

Table A-2

$M_{Ne} = 20.18 \text{ kg/kmol}$ $M_{Ar} = 39.95 \text{ kg/kmol}$

$$N_{Ne} = \frac{P_1 V_1}{R T_1} = \frac{(\text{kPa})(.45\text{m}^3)}{(8.314)(298\text{K})}$$

$$N_{Ar} = \frac{P_1 V_1}{R T_1} = \frac{(2\text{ kPa})(.45\text{m}^3)}{(8.314)(327)}$$

$N_{Ne} = .0185 \text{ kmol}$

$N_{Ar} = .0335 \text{ kmol}$

$N_{Ne} + N_{Ar} = N_m$

$.0375 + .0185 = .0520 \text{ kmol}$

$-Q_{out} = \Delta U = \Delta U_m + \Delta U_{Ar}$

$= [mc_v(T_m - T_1)]_{Ne} + [mc_v(T_m - T_1)]_{Ar}$

$-153 = (.0185)(20.18)(.6179 \cdot C^\circ)(T_m - 20^\circ C)$

$+ (.375)(39.95)(.3122 \cdot C^\circ)(T_m - 54^\circ C$

$T_m = 16.2^\circ C + 273 K$

$T_m = 289.2 K$

b) Final pressure

$$P_m = \frac{N_m R T}{V_m} = \frac{(.052 \text{ kmol})(8.314)(289.2K)}{.9\text{m}^3}$$

$P_m = 138.1 \text{kPa}$

13.59) w_{in}=?
q_{out}=?

Table A-1 and A-2

$M_{CH_4} = 16.043$ kg/kmol $M_{C_3H_8} = 44.097$ kg/kmol

$M_{C_4H_{10}} = 58.124$ kg/kmol

$N_{CH_4} = \frac{m_{CH_4}}{M_{CH_4}} = \frac{60\text{ kg}}{16\text{ kg/kmol}} = 3.75$ kmol

$N_{C_3H_8} = \frac{m}{M} = \frac{25\text{ kg}}{44\text{ kg/kmol}} = .568$ kmol

$N_{C_4H_{10}} = \frac{m}{M} = \frac{15\text{ kg}}{58\text{ kg/kmol}} = .258$ kmol

$N_m = N_{CH_4} + N_{C_3H_8} + N_{C_4H_{10}}$

$N_m = 4.576$ kmol

$M_m = \frac{m_m}{N_m} = \frac{100\text{ kg}}{4.576\text{ kmol}}$

$m_m = 21.85$ kg/kmol

$R = \frac{R_u}{m_m} = \frac{8.314}{21.85\text{ kg/kmol}} = .385$ kJ/kg·K

$w_{in} = RT \ln \frac{P_2}{P_1} = (.385\text{ kJ/kg·K})(293\text{K}) \ln\left(\frac{100\text{ kPa}}{1\text{ kPa}}\right)$

$w_{in} = 257$ kJ/kg

$E_{in} - E_{out} = \Delta E_{system}$

$E_{in} - E_{out} = 0$

$E_{in} = E_{out}$

$m h_1 w_{in} = m h_2 q_{out}$

$q_{out} + h_2 = h_1 + w_{in} = h_2 - h_1 - q_{out}$

$= c_p(T_2 - T_1) + q_{out}$

$= c_p \cdot 0 \, q_{out}$

$w_{in} = q_{out}$

$257\text{ kJ/kg} = q_{out}$